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NACA

RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Navy Department

TANK TESTS OF AN ALTERNATE HULL FORM FOR THE CONSOLIDATED VULTEE PB2Y-3 AIRPLANE

By

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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TANK TESTS OF AN ALTERNATE HULL FORM FOR THE CONSOLIDATED VULTEE PB2Y-3 AIRPLANE

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SUMMARY

Tests have been made in Langley tank no. 1 of a dynamic model of the Consolidated Vultee PB2Y-3 airplane. These tests were made using an alternate hull form, the purpose of which was to reduce the bow spray and eliminate the landing instability which are objectionable features of the production design. The major differences from the PB2Y-3 hull included a deeper step to improve the landing stability, and a lengthened forebody and increased beam to reduce the spray in the propellers and on the flaps.

The tests showed that the spray characteristics of the revised hull form were much better than that of the production design. In addition the take-off and landing stability of the model with the alternate hull were satisfactory.

INTRODUCTION

The tests described in this report were made to determine the hydrodynamic characteristics of a proposed alternate form of hull for the Consolidated Vultee PB2Y-3 airplane. This hull was designed to eliminate the more objectionable landing instability inherent in the production design of the airplane, to reduce the bow spray, and to improve the take-off stability at forward positions of the center of gravity.

The major differences from the PB2Y-3 airplane include a deeper step to improve the landing stability, a lengthened forebody and increased beam to reduce the spray in the propeller and on the flaps, and a more forward position of the main step. The lines for the new hull were derived from a streamline body of revolution.

Tests of a 1/8-size model were made to determine the take-off and landing stability and the spray characteristics at gross loads corresponding to 76,000, 86,000, and 96,000 pounds, full size. Comparisons are made with similar results for a 1/8-size model of the production design (Langley tank model 165) and for a 1/8-size model of the production design with increased length of hull (Langley tank model 165A-1).

These tests were requested by the Bureau of Aeronautics, Navy Department in their letter to the Committee, Aer-E-23-FZ, C-78903, C-92183, VPB2Y-3/F13-1, C5414 of March 18, 1943, and were made in Langley tank no. 1 during September 1944.

DESCRIPTION OF MODEL

The model, designated in the Langley tank as model 161, is a 1/8-size, powered, dynamic model of a modified PB2Y-3 airplane. The model was designed and constructed at the Langley Laboratory. Important dimensions of the model are given in Table I, together with the dimensions of a subsequent modification, designated model 161A-1. Photographs of models 161 and 161A-1 are shown in figure 1. A body plan of model 161A-1 is shown in figure 2.

The dimensions of a 1/8-size model of the production design of the PB2Y-3 (model 165) and those for the same model with lengthened hull (model 165A-1) are also included in table I. A complete description of these models is given in reference 1.

Models 161 and 161A-1 are compared in figure 3, models 161A-1 and 165 in figure 4, models 161A-1 and 165A-1 in figure 5, and models 165 and 165A-1 in figure 6.

The wing, propellers and propeller blade angle of models 161 and 161A-1 were the same as those of model 165. A single tail arrangement was used instead of the twin tail arrangement of the PB2Y-3.

APPARATUS AND PROCEDURE

Aerodynamic tests.- The effective thrust was measured at constant speed with the model in the air at a trim of 0°. The effective thrust of model 161A-1 with a propeller blade angle of 8° at 3/4 radius and an rpm of 6900 is shown in figure 7 together with the scale thrust for the full size PB2Y-3. (See reference 1.)

The aerodynamic lift and pitching moments with and without power were measured with the model in the air at a height above the water sufficient to allow clearance at a trim of 16°. The model was towed at a constant speed of approximately 40 feet per second. Aerodynamic lift and pitching-moment coefficients are presented in figures 8 and 9. The pitching moments are referred to a location of the center of gravity of 24 percent mean aerodynamic chord. The stabilizer was set -6° to the base line. With this setting the aerodynamic pitching-moment coefficients, with neutral elevators, approximated those of model 165, reference 1.

Hydrodynamic tests.- The trim and total resistance of model 161A-1, without power, were measured at the design load, with two elevator settings, for speeds up to take-off. The trim limits of stability were determined at constant speeds to take-off. (The definition of, and method for determining these limits, are given in reference 2.)

The variation of trim with speed during take-off at various positions of the center of gravity was determined at a constant rate of acceleration of 1 foot per second per second. The tests were made at three gross loads and three deflections of the elevator. The loads tested and the corresponding full-size loads are given in the following table:

Model load (lb)	Full-size load (lb)
147.5	76,000
166.5	86,000
186.0	96,000

From the trim tracks the variation of maximum amplitude of porpoising with position of center of gravity was determined for the three gross loads at neutral and -25° elevators (taking neutral elevators for forward positions of the center of gravity and -25° elevators for after positions of the center of gravity). From this, the variation of range of stable positions of the center of gravity with change in gross load was determined, assuming 2° amplitude of porpoising as the acceptable condition.

Still and motion pictures were taken of the bow spray at various loads and speeds. The behavior of the model during landing was recorded by motion pictures.

RESULTS AND DISCUSSION

During preliminary tests of model 161, violent upper-limit porpoising was encountered. It was found that if the porpoising was allowed to build up to a sufficiently large amplitude, the model porpoised between the upper and lower trim limits and recovery by use of the elevators was not always possible. An undesirable flow of water over the tail extension was noted during landings, and at landing trims above 10° the model encountered the upper trim limit and porpoised. An increase in the depth of step did not eliminate these undesirable characteristics and further tests on model 161 were discontinued. The afterbody and tail extension of model 161 were modified and preliminary tests to determine a satisfactory depth of step were made. The final configuration, shown in figure 1, was designated as model 161A-1, and complete tests were made with this model.

Characteristics of model 161A-1.- Photographs of the spray in the propellers of model 161A-1 for three gross loads are shown in figure 10. The speeds at which spray enters and clears the propellers for various gross loads is shown in figure 11. The spray characteristics of the model were considered to be satisfactory up to the heaviest load tested, which corresponds to a full-size gross load of 96,000 pounds.

The variation of trim with speed at three gross loads and three elevator settings with several center-of-gravity locations is shown in figure 12. The variation of the maximum amplitude of porpoising with position of the center of gravity for the three gross loads tested is shown in figure 13. The variation of the range of stable positions of the center of gravity with change in gross load is shown in figure 14. From this figure it can be seen that at a gross load of 76,000 pounds, stable take-offs with neutral elevators were possible at positions of the center of gravity aft of 26 percent mean aerodynamic chord, and with up elevators at positions of the center of gravity forward of 29 percent.

Model 161A-1 was stable on landing, and the depth of step was considered satisfactory with regard to both stability and resistance. The trim limits of stability for model 161A-1 are presented in figure 15. The resistance and trim of model 161A-1 at the design load and at two elevator settings are presented in figure 16, together with similar data for model 165A-1.

Comparison of models 161A-1, 165 and 165A-1.- From observation and study of photographs it appears that the spray through the propellers of model 161A-1 is much less severe than the spray through the propellers of model 165. The spray through the propellers of models 161A-1 and 165A-1is approximately the same in volume and duration.

Comparisons of the range of stable positions of the center of gravity with gross load for models 161A-1 and 165A-1 is presented in figure 14. The range of stable positions of the center of gravity is further forward for model 161A-1 than for model 165A-1, but within the accuracy of the tests the spread between the forward and aft limits is approximately the same for both models.

It can be seen from figure 16 that at hump speed the resistances and trims of models 161A-1 and 165A-1 are approximately the same. At speeds beyond the hump however, they are higher for model 161A-1 than for model 165A-1.

CONCLUSIONS

1. The spray characteristics of model 161A-1 were satisfactory up to a load corresponding to a full-size gross load of 96,000 pounds. The spray through the propellers of model 161A-1 was much less severe than the spray through the propellers of model 165, and approximately the same as the spray through the propellers of model 165A-1.

2. At a load corresponding to a full-size gross load of 76,000 pounds stable take-offs of model 161A-1 with neutral elevators were possible at positions of the center of gravity aft of 26 percent mean aerodynamic chord, and with up elevators at positions of the center of gravity forward of 29 percent. The range of stable positions of the center of gravity was further forward for model 161A-1 than for model 165A-1, and the extent was approximately the same.

3. Model 161A-1 was stable on landing, as was model 165A-1.

4. The hump resistance of model 161A-1 was approximately the same as that of model 165A-1, but at speeds beyond the hump, the resistance of model 161A-1 was greater than that of model 165A-1.

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REFERENCES

1. Land, Norman S., and Woodward, David R.: Tank Tests of a 1/8-Full-Size Dynamic Model of the Consolidated-Vultee PB2Y-3 Airplane with a Lengthened Forebody and Afterbody and Various Modifications of the Step. NACA MR for Bur. Aero., March 4, 1944.

Unclass 10-1-45

2. Olson, Roland E., and Land, Norman S.: The Longitudinal Stability of Flying Boats as Determined by Tests of Models in the NACA Tank. Part I - Methods Used for the Investigation of Longitudinal Stability Characteristics. NACA ARR, November 1942.

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TABLE I

	Model 161	Model 161A-1	Model 165	Model 165A-1
Hull:				
Maximum beam, in.	18.76	18.76	15.75	15.75
Beam at step, in.	18.16	18.16	15.75	15.75
Angle of dead rise at step, deg	20	20	22.5	22.5
Angle of forebody keel, deg	1.3	1.3	1.0	1.0
Angle of afterbody keel, deg	5.7	5.0	6.25	6.25
Length of forebody, in. to centroid for models 165 and 165A-1	57.79	57.79	46.36	57.32
Length of afterbody, in. to centroid for models 165 and 165A-1	40.36	40.36	35.20	43.72
Length of forebody to point of step, in.	----	-----	49.39	60.35
Length of afterbody from point of step, in.			32.17	40.69
Over-all length, in.	139.50	139.50	118.50	130.90
Length-beam ratio	5.23	5.23	5.18	6.42
Forebody-afterbody ratio	1.43	1.43	1.32	1.31
Type of step	Trans.	Trans.	30°-V	30°-V
Depth of step at centroid, percent beam	-----	-----	3.2	7.2
Depth of step at keel, percent beam	8.0	10.7	5.5	9.7

Wing (same wing used for all models)	
Area, sq ft	27.8
Span, in.	172.5
Root chord, in.	30.0
Tip chord, in.	16.5
Angle of wing setting, deg	3
Length, mean aerodynamic chord, in.	24.29
Propellers (same propellers used for all models)	
Diameter, in.	19.5
Number of propellers	4
Blades per propeller	3
Pitch at 3/4 radius, deg	8
Thrust line, angle to base line, deg	0

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FIGURE LEGENDS

Figure 1.- Models 161 and 161A-1. Side-view photographs.

Figure 2.- Model 161A-1, body plan.

Figure 3.- Models 161 and 161A-1.

Figure 4.- Models 161A-1 and 165.

Figure 5.- Models 161A-1 and 165A-1.

Figure 6.- Models 165 and 165A-1.

Figure 7.- Model 161A-1. Effective thrust at propeller speed of 6900 rpm. Blade angle, 8° at 3/4 radius; trim 0°.

Figure 8.- Model 161A-1. Aerodynamic characteristics with power off; $\delta_f = 20^{\circ}$; $\delta_s = -6^{\circ}$.

Figure 9.- Model 161A-1. Aerodynamic characteristics with power on. Blade angle, 8° at 3/4 radius; 6900 rpm; $\delta_f = 20^{\circ}$; $\delta_s = -6^{\circ}$.

Figure 10.- Model 161A-1. Spray in propellers. 20° flaps; 0° elevator

(a) Speed = 7.5 fps

Figure 10.- Model 161A-1. Continued.

(b) Speed = 10.0 fps

Figure 10.- Model 161A-1. Continued.

(c) Speed = 12.5 fps

Figure 10.- Model 161A-1. Continued.

(d) Speed = 15.0 fps

Figure 10.- Model 161A-1. Continued.

(e) Speed = 17.5 fps

Figure 10.- Model 161A-1. Concluded.

(f) Speed = 20.0 fps

FIGURE LEGENDS - Concluded

Figure 11.- Model 161A-1. Speeds at which spray enters and clears the propellers at various gross loads. $\delta_f = 20^\circ$; $\delta_e = 0^\circ$; propeller speed 6900 rpm.

Figure 12.- Model 161A-1. Variation of trim with speed for various elevator deflections and positions of the center of gravity. Propeller rpm 6900; $\delta_f = 20^\circ$; $\delta_e = -6^\circ$.

(a) $\Delta_o = 147.5$ lb

Figure 12.- Model 161A-1. Continued

(b) $\Delta_o = 166.5$ lb

Figure 12.- Model 161A-1. Concluded

(c) $\Delta_o = 186.0$ lb

Figure 13.- Models 161A-1, 165, and 165A-1. Variation of maximum amplitude of porpoising with position of center of gravity, $\delta_f = 20^\circ$.

Figure 14.- Models 161A-1 and 165A-1. Variation of stable range of center of gravity positions with gross load. $\delta_f = 20^\circ$.

Figure 15.- Models 161A-1, 165, and 165A-1. Comparison of trim limits of stability, $\Delta_o = 147.5$ pounds; $\delta_f = 20^\circ$; propeller rpm. 6900.

Figure 16.- Models 161A-1 and 165A-1. Free-to-trim resistance without power. $\Delta_o = 147.5$ pounds $\delta_f = 20^\circ$; center of gravity 28 percent mean aerodynamic chord.

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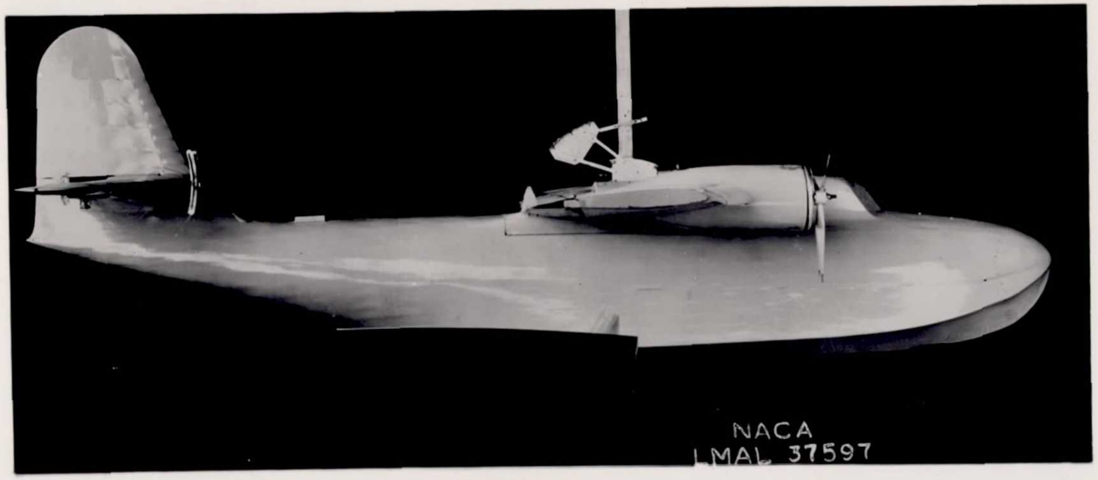

Model 161

Model 161A-1

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Figure 1.- Models 161 and 161A-1. Side-view photographs.

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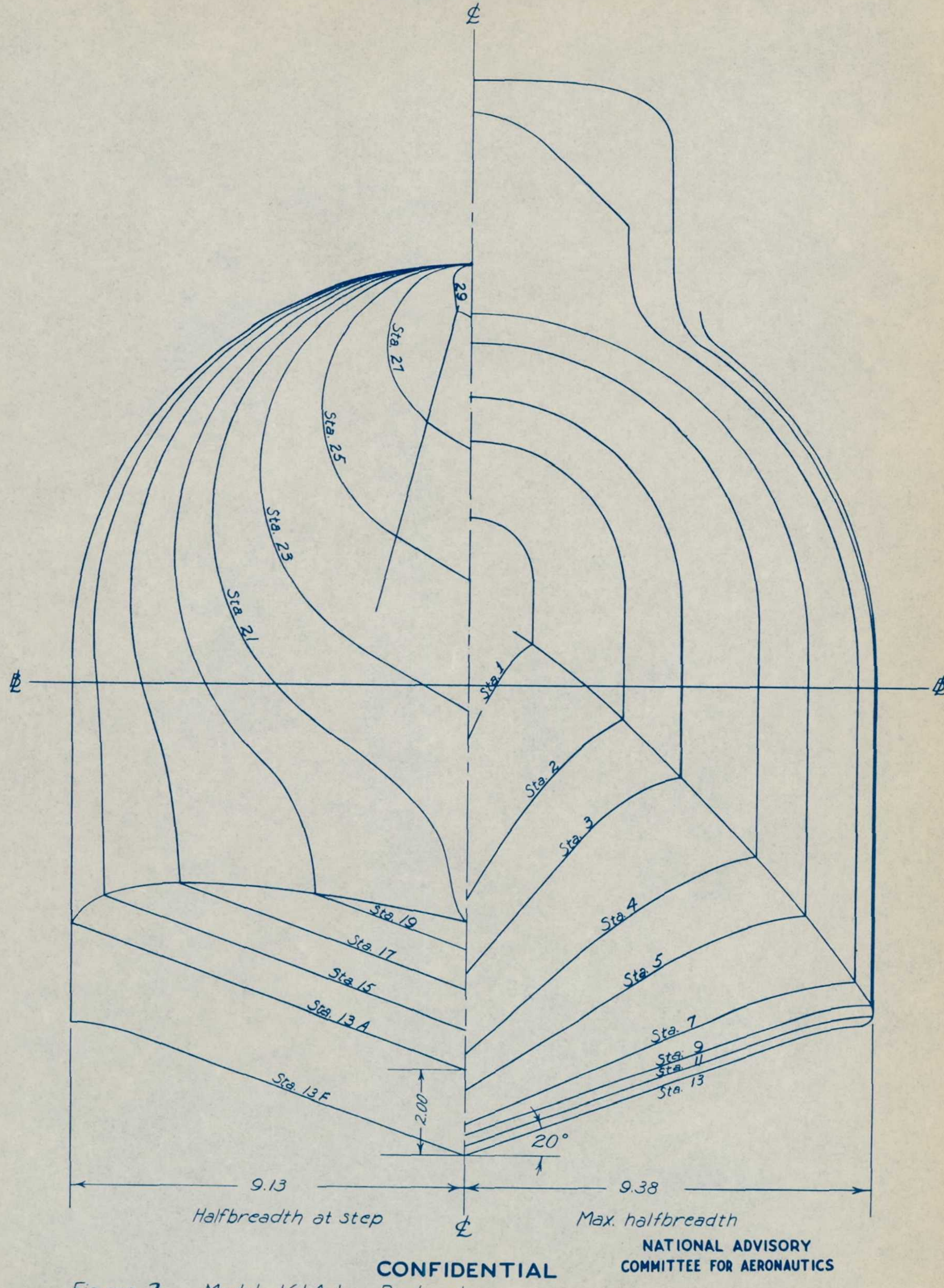

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Figure 2 .- Model 161A-1, Body plan.

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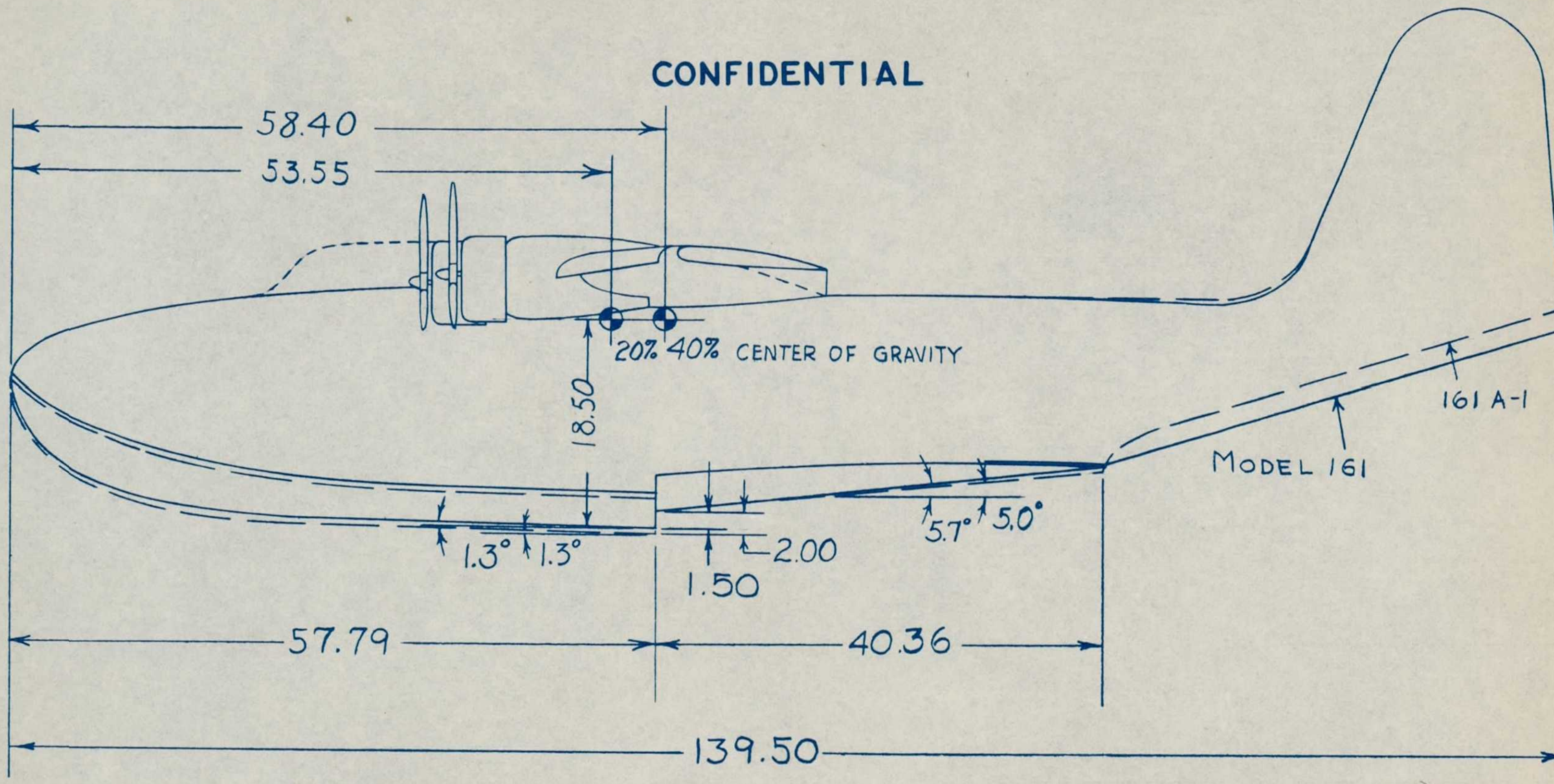

ALL DIMENSIONS IN INCHES

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FIGURE 3 .– MODELS 161 AND 161 A-1.

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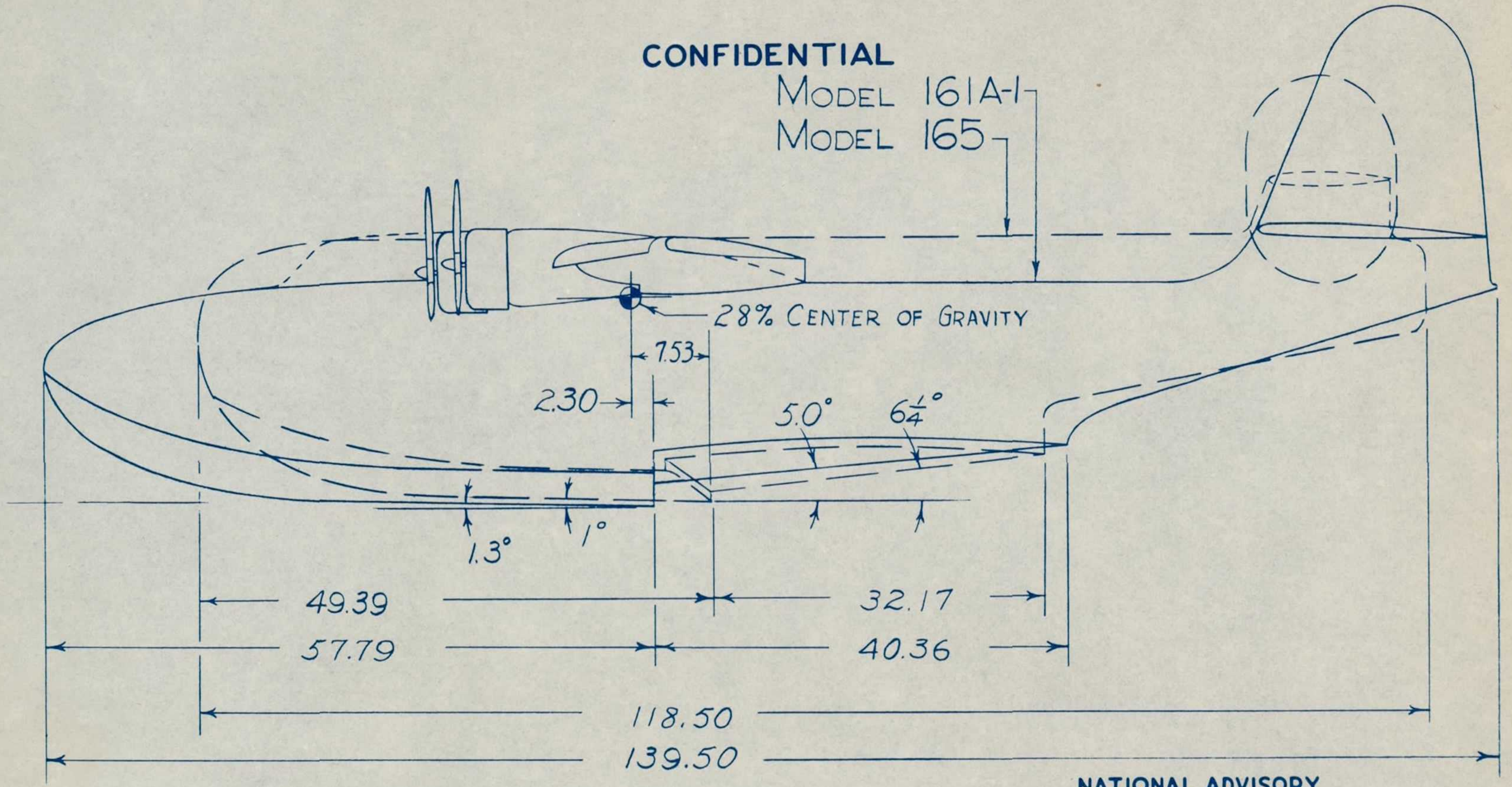

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All dimensions in inches.

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Figure 4. — Models 161A-1 and 165.

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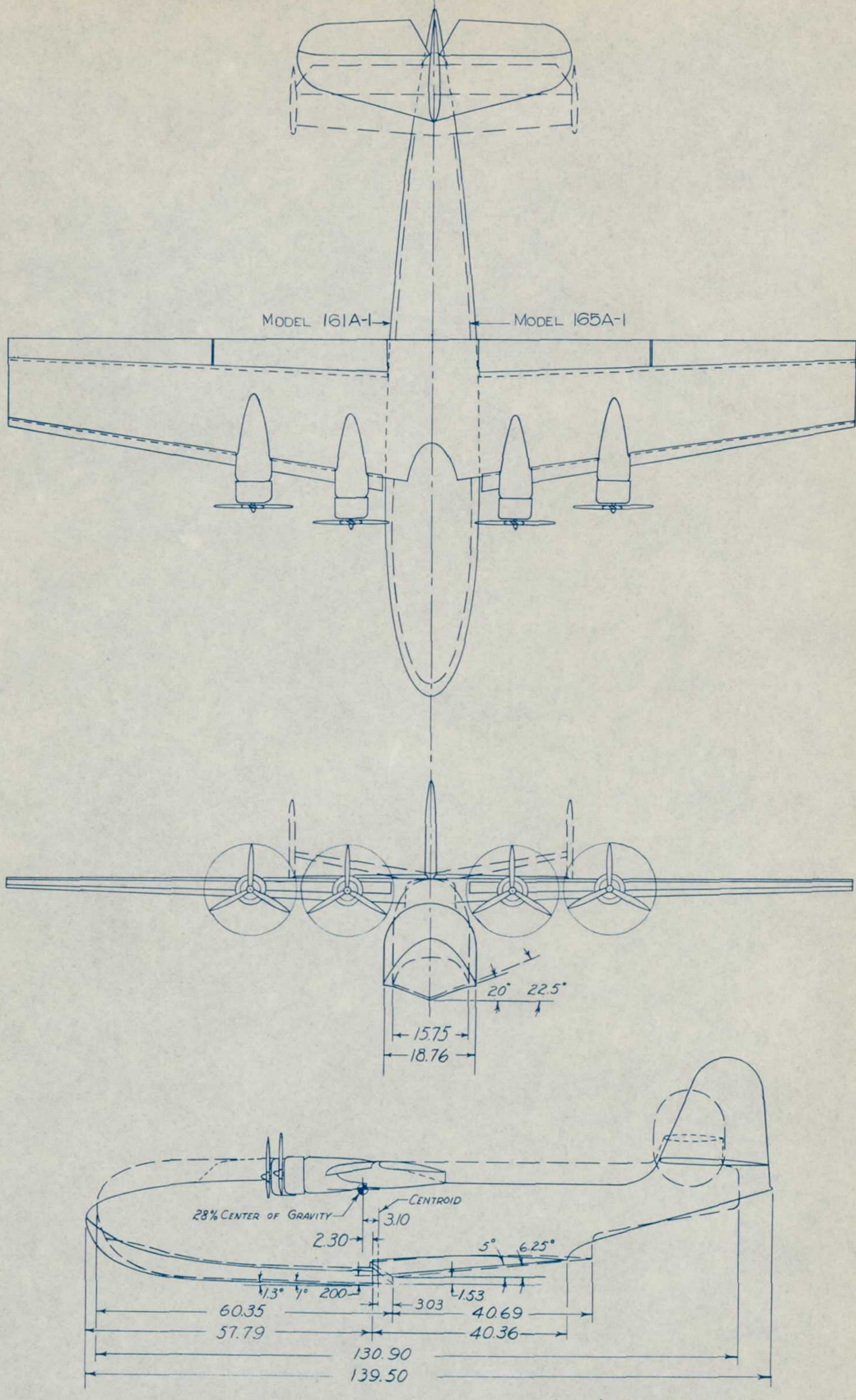

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FIGURE 5. — MODELS 161A-1 AND 165A-1.

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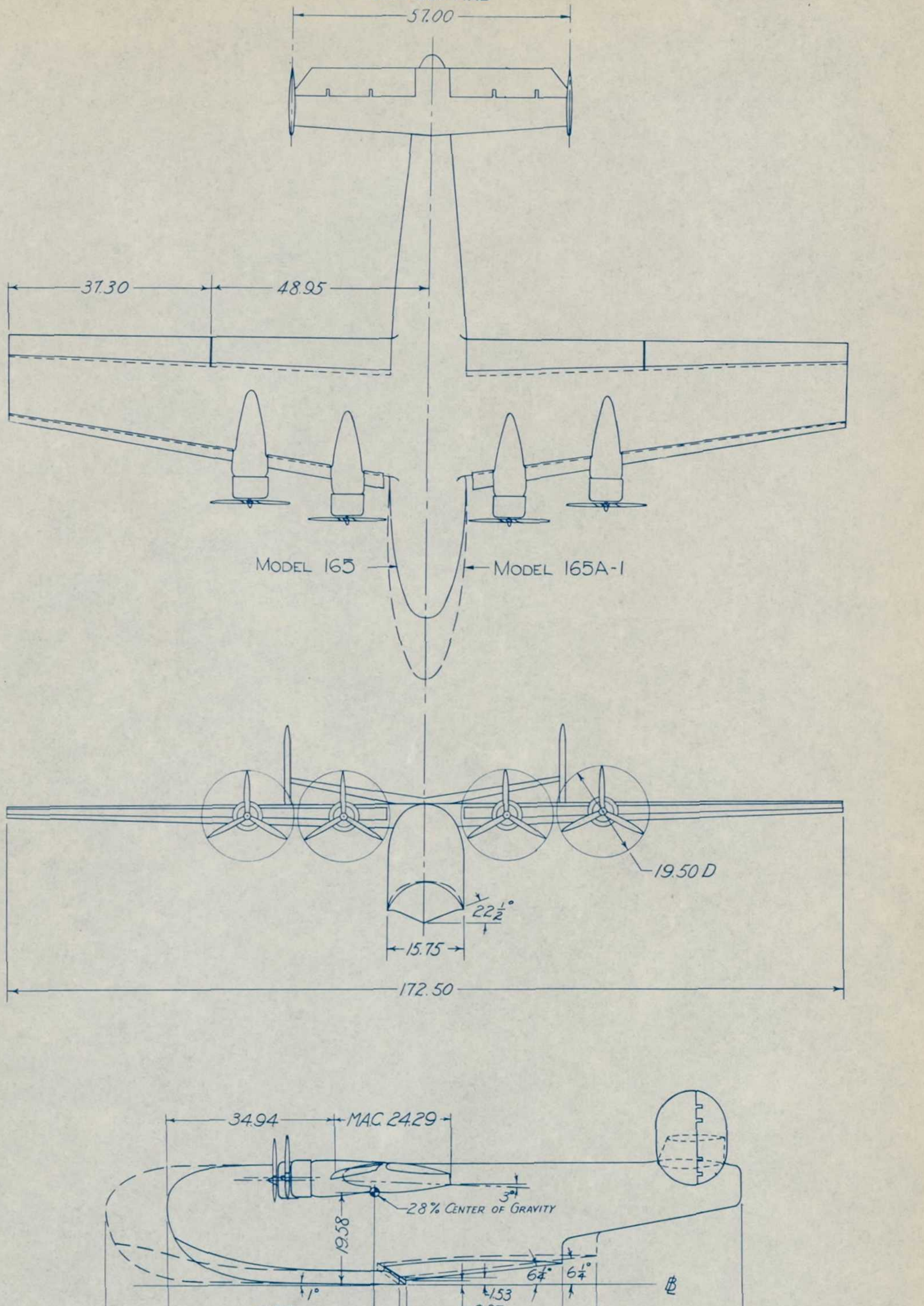

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Figure 6. — Models 165 and 165A-1

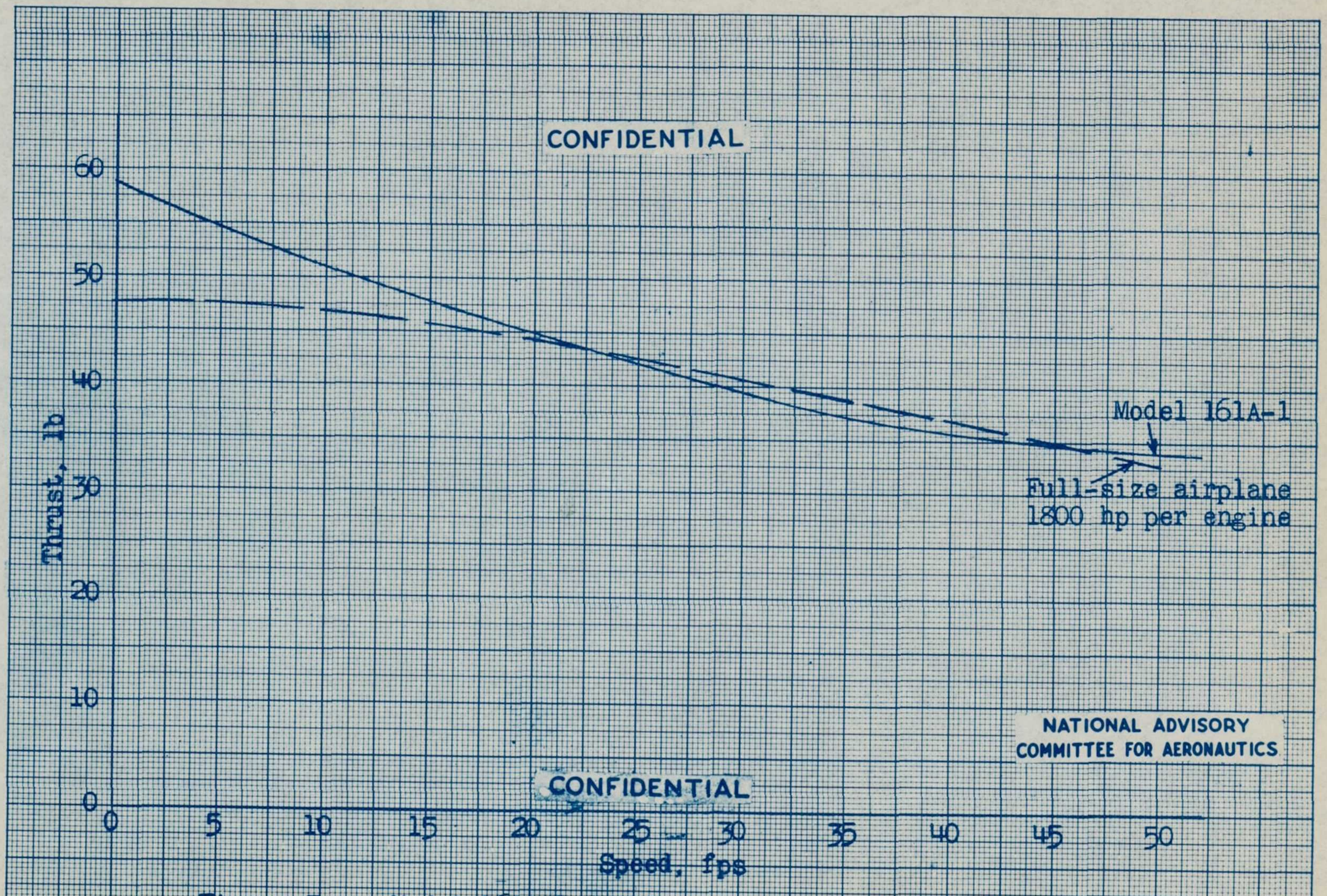

Figure 7.- Model 161A-1. Effective thrust at propeller speed of 6900 rpm. Blade angle, 8° at 3/4 radius; trim 0°.

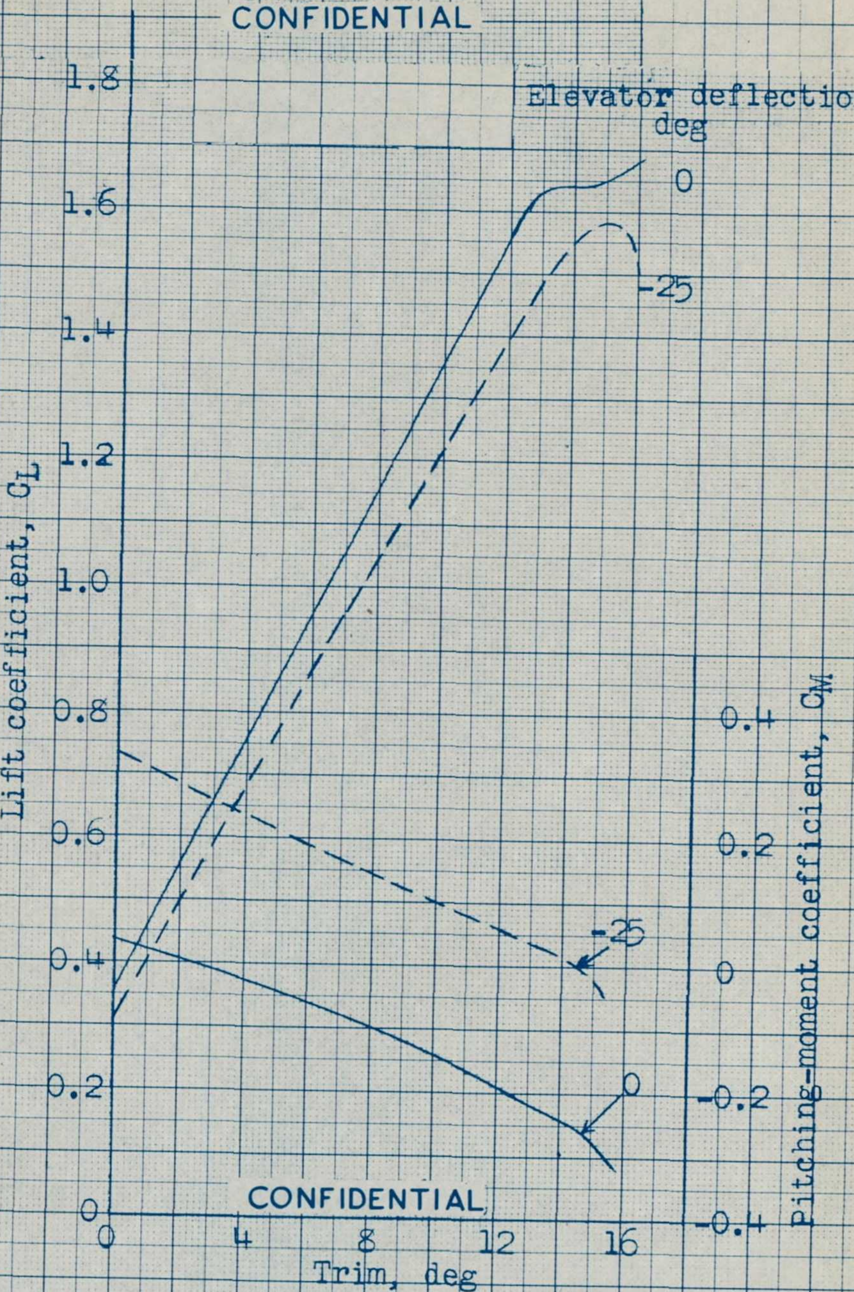

Figure 8.- Model 161A-1. Aerodynamic characteristics with power off; $\delta_f = 20^0$; $\delta_s = -6^0$.

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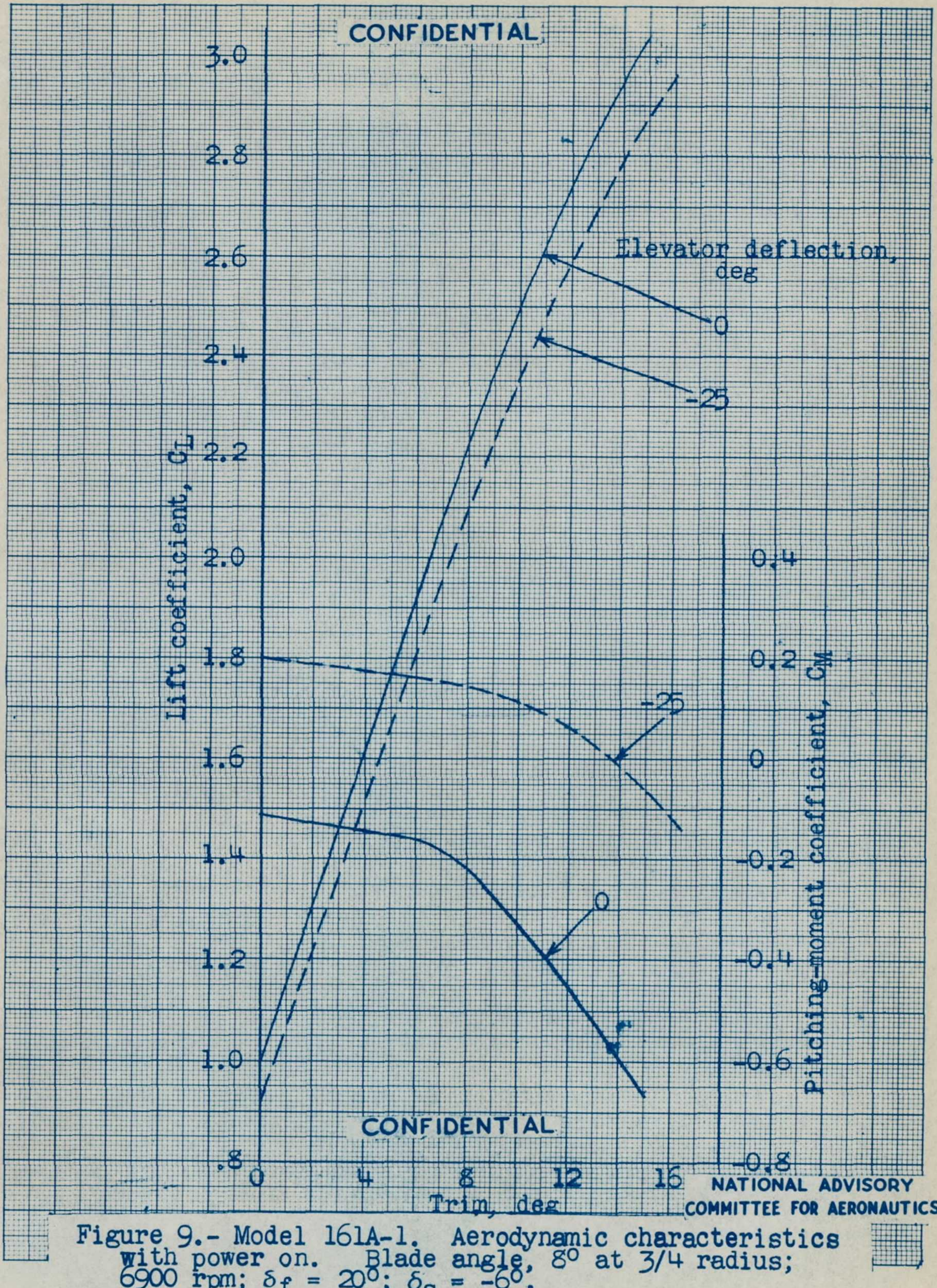

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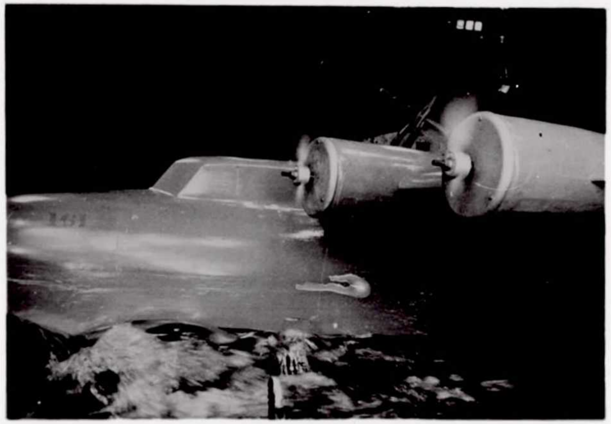
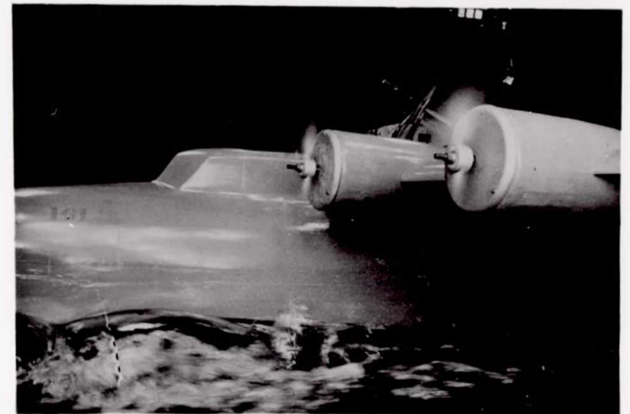
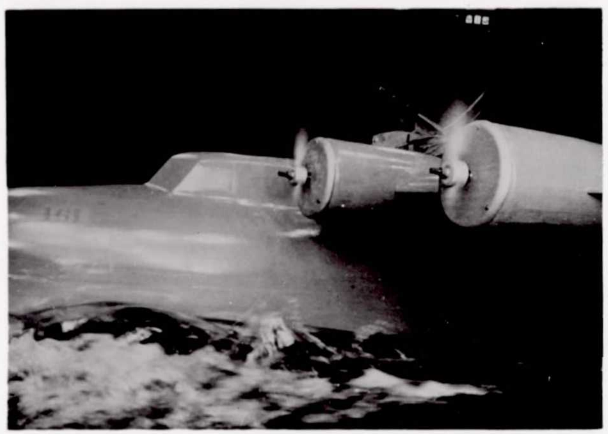
Figure 9.- Model 161A-1. Aerodynamic characteristics with power on. Blade angle, 8° at 3/4 radius; 6900 rpm; $\delta_f = 20^0$; $\delta_s = -6^0$.



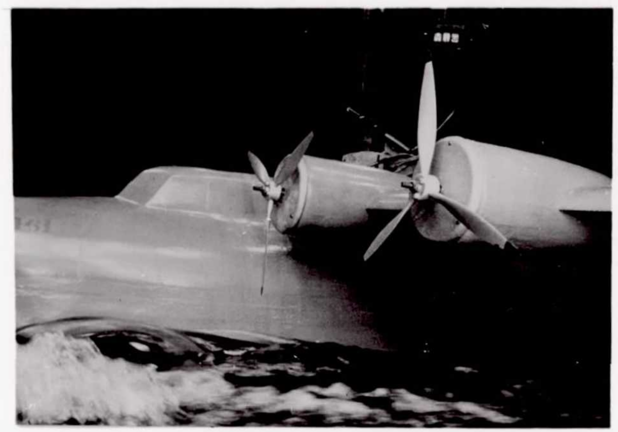
Δ_o = 147.5 lb. τ = 3.5°
Power on



Δ_o = 166.5 lb. τ = 3.6°
Power on



Δ_o = 186.0 lb. τ = 3.4°
Power on



Δ_o = 186.0 lb. τ = 5.0°
Power off

(a) Speed = 7.5 fps

Figure 10.- Model 161A-1. Spray in propellers. 20° flaps; 0° elevator

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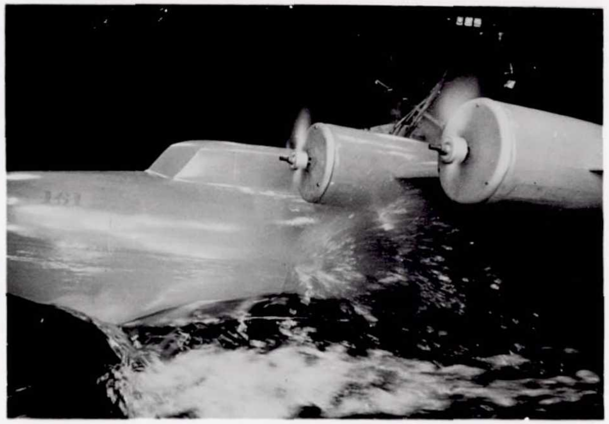
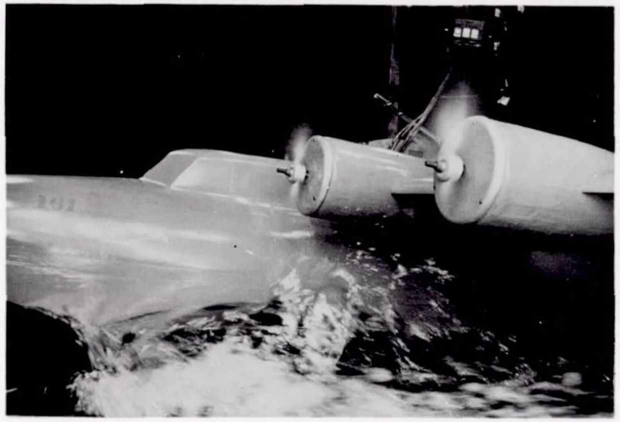
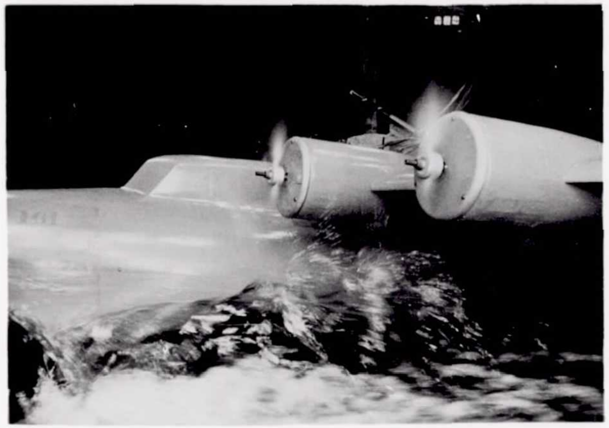


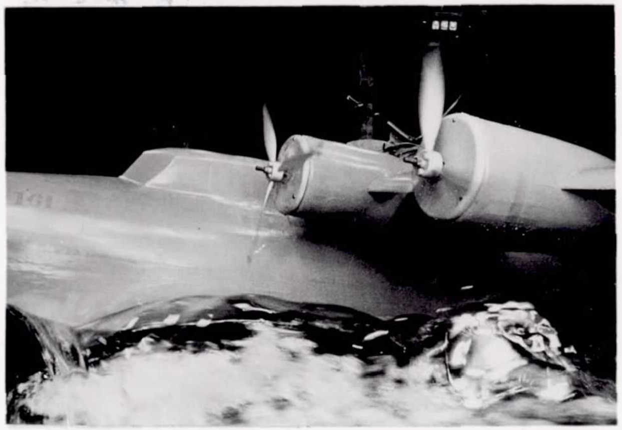
Δ_o = 147.5 lb. τ = 4.8°
Power on



Δ_o = 166.5 lb. τ = 5.1°
Power on



Δ_o = 186.0 lb. τ = 5.0°
Power on



Δ_o = 186.0 lb. τ = 7.5°
Power off

(b) Speed = 10.0 fps

Figure 10.- Model 161A-1. Continued.

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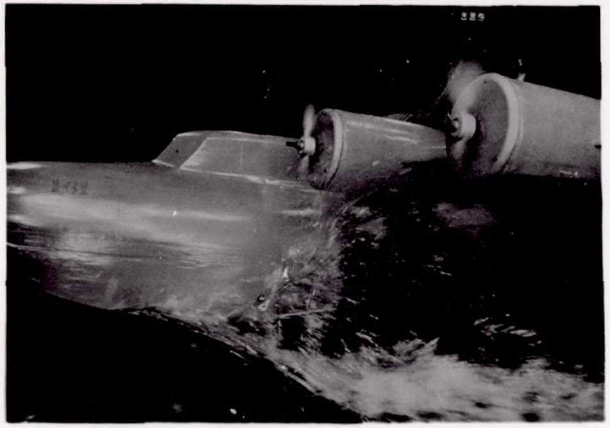
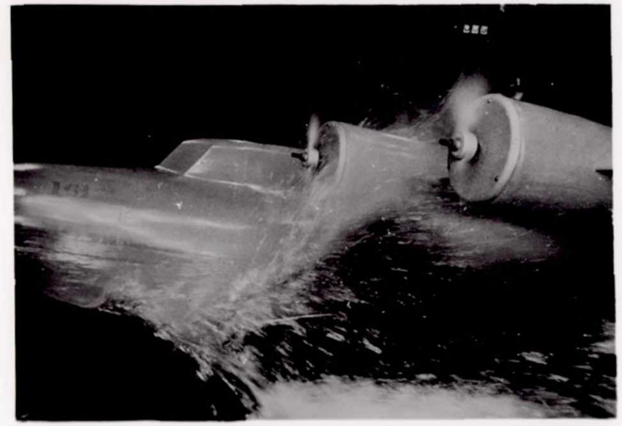
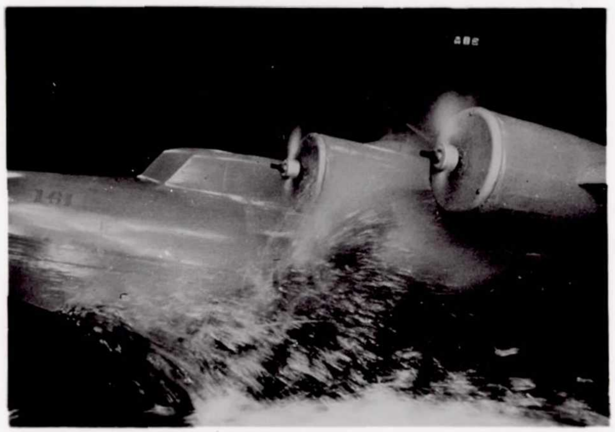


Δ_o = 147.5 lb. τ = 5.7°
Power on



Δ_o = 166.5 lb. τ = 6.1°
Power on

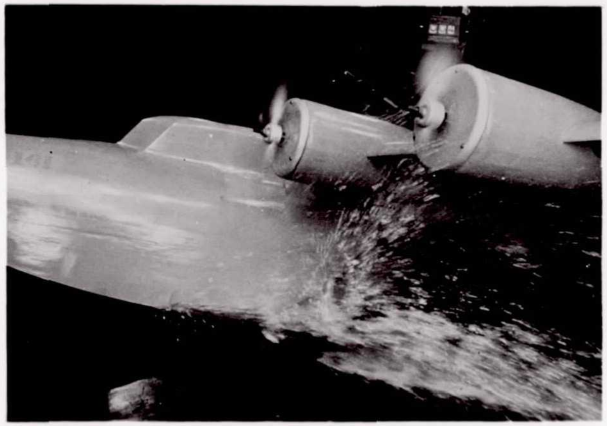


Δ_o = 186.0 lb. τ = 6.5°
Power on

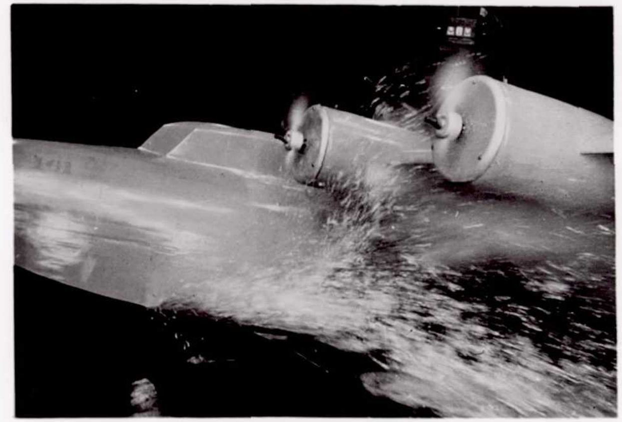
Δ_o = 186.0 lb. τ = 8.0°
Power off

(c) Speed = 12.5 fps

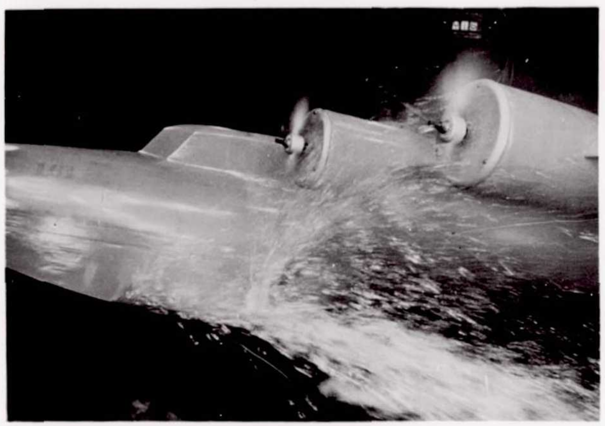
Figure 10.- Model 161A-1. Continued.



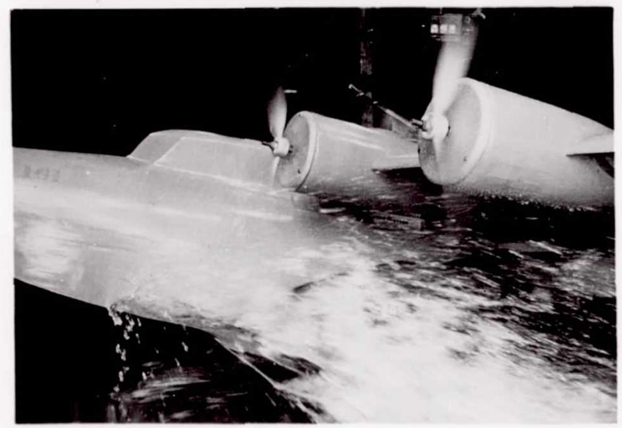
Δ_o = 147.5 lb. τ = 7.5°
Power on



Δ_o = 166.5 lb. τ = 7.7°
Power on



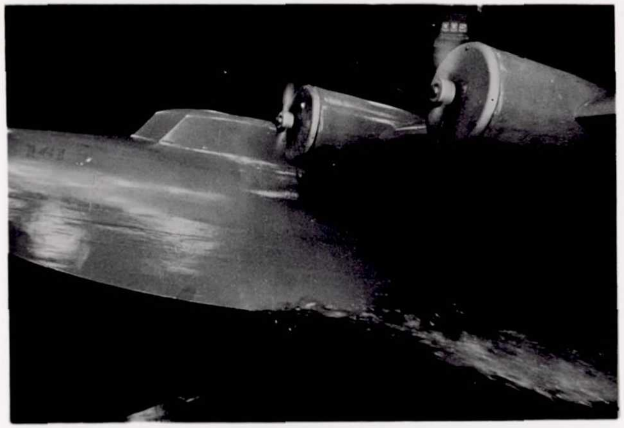
Δ_o = 186.0 lb. τ = 7.7°
Power on



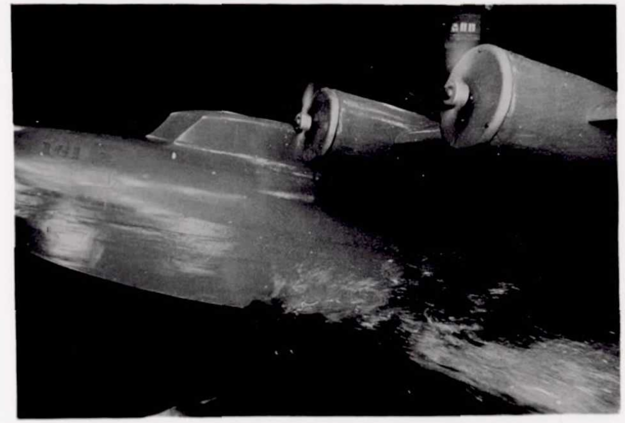
Δ_o = 186.0 lb. τ = 9.9°
Power off

(d) Speed = 15.0 fps

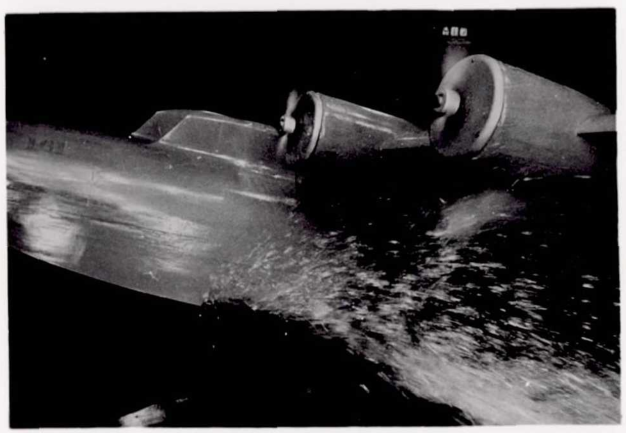
Figure 10.- Model 161A-1. Continued.



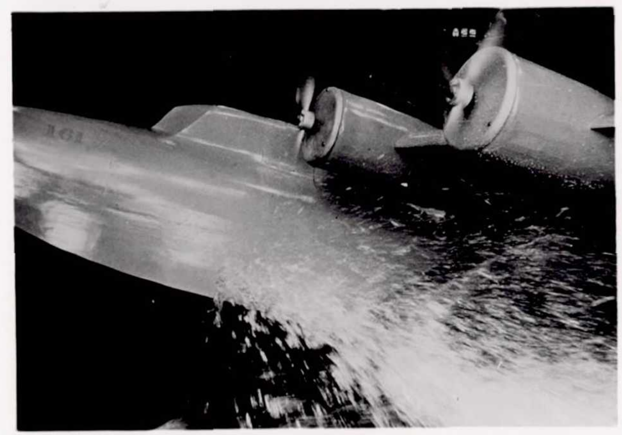
Δ_o = 147.5 lb. τ = 8.6°
Power on



Δ_o = 166.5 lb. τ = 8.8°
Power on



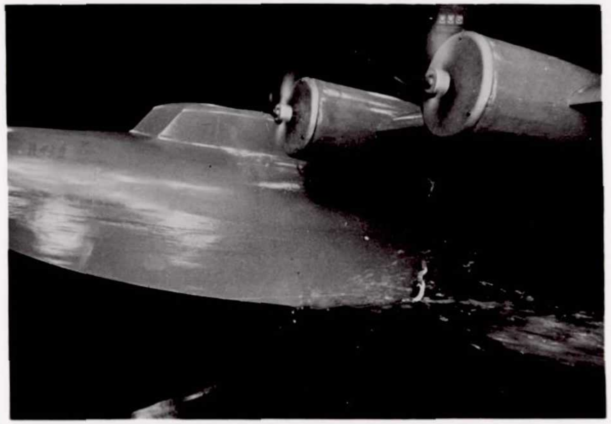
Δ_o = 186.0 lb. τ = 9.5°
Power on



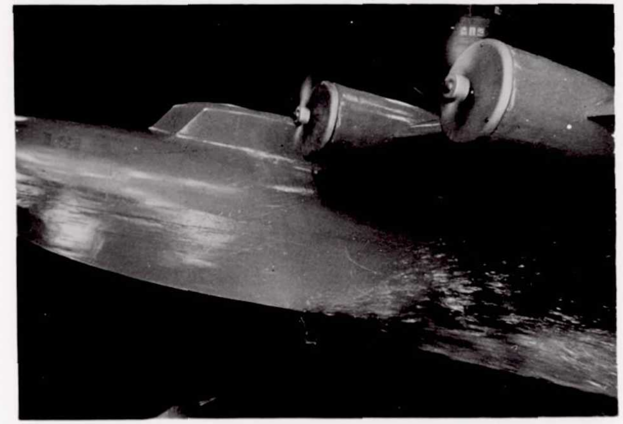
Δ_o = 186.0 lb. τ = 12.6°
Power off

(e) Speed = 17.5 fps

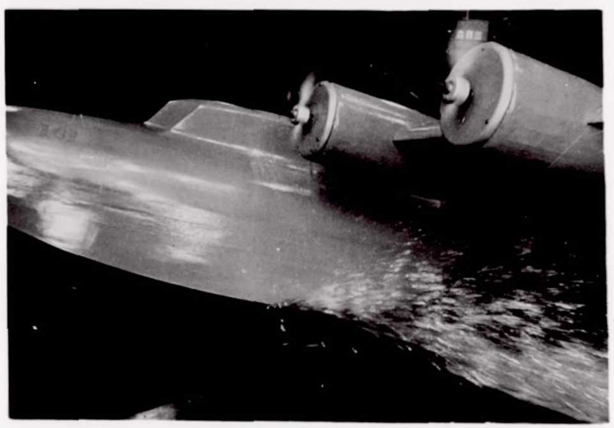
Figure 10.- Model 161A-1. Continued.



Δ_o = 147.5 lb. τ =
Power on



Δ_o = 166.5 lb. τ = 8.5°
Power on



Δ_o = 186.0 lb. τ = 9.5°
Power on

Δ_o = 186.0 lb. τ = 12.8°
Power off

(f) Speed = 20.0 fps

Figure 10.- Model 161A-1. Concluded.

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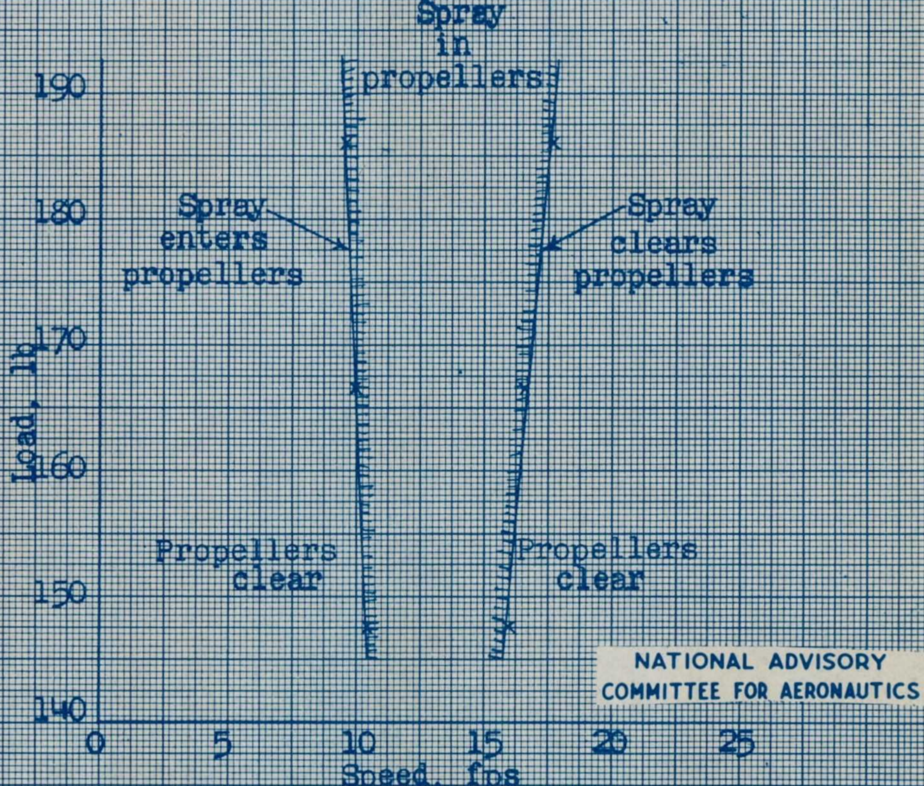

Figure 11.- Model 161A-1. Speeds at which spray enters and clears the propellers at various gross loads. $\delta_f = 20^0$; $\delta_e = 0^0$; propeller speed 6900 rpm.

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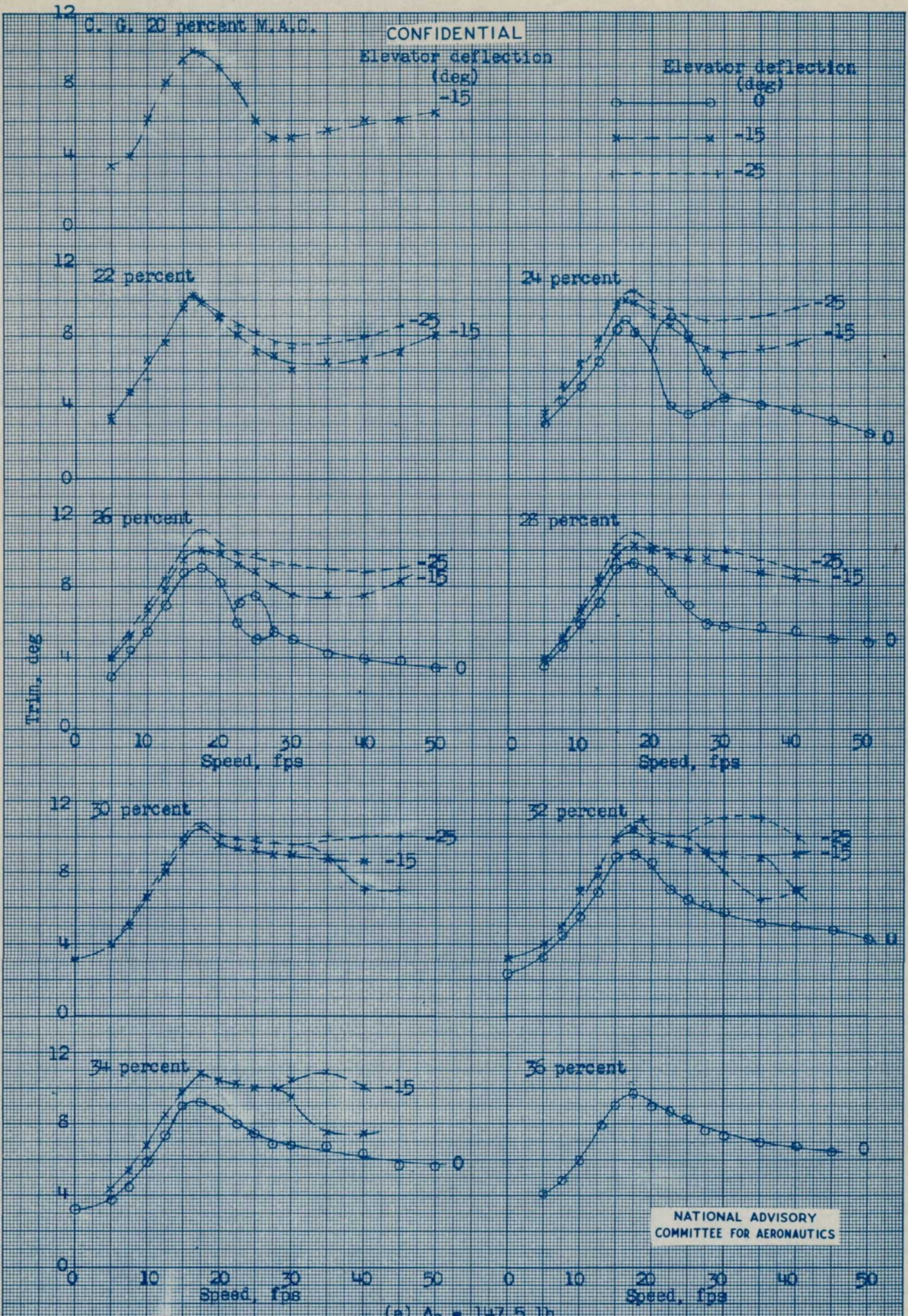

(a) Δ_0 = 147.5 lb

Figure 12.- Model 161A-1. Variation of trim with speed for various elevator deflections and positions of the center of gravity. Propeller rpm 6900; $\delta_f = 20^\circ$; $\delta_s = -6^\circ$

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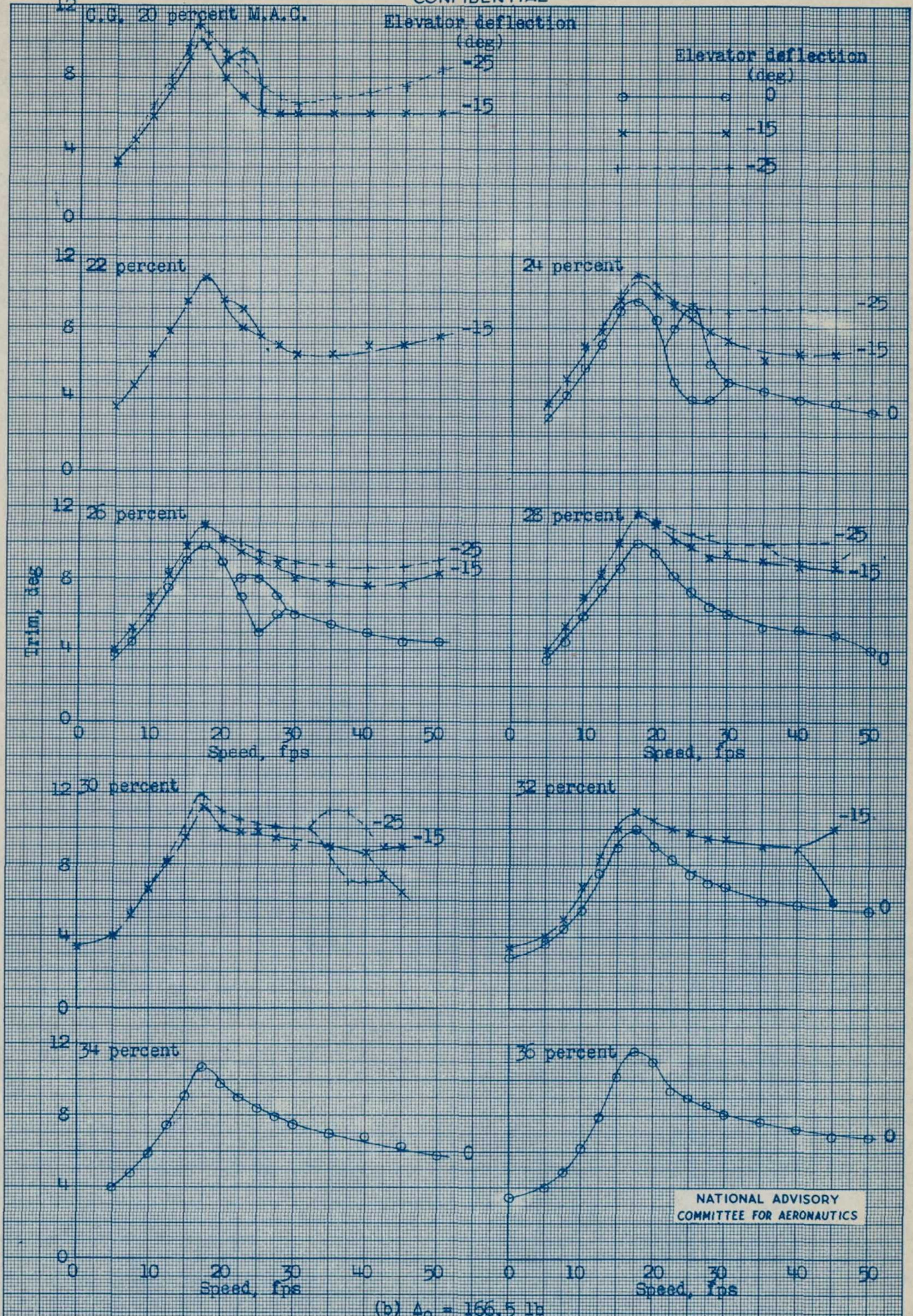

(b) Δ_0 = 166.5 lb

Figure 12.- Model 161A-1.- Continued

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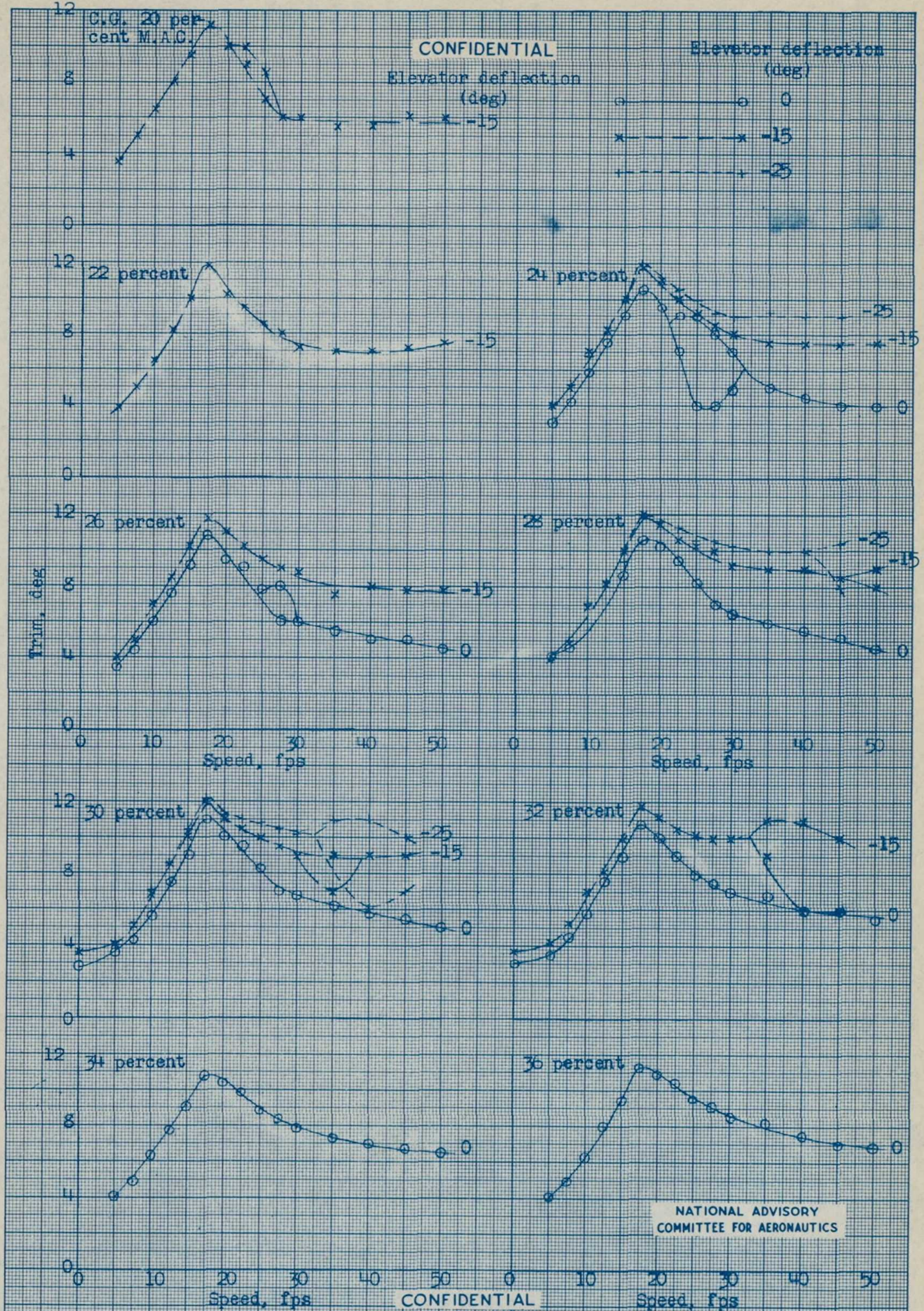

(c) Δ_0 = 186.0 lb

Figure 12.- Model 161A-1.- Concluded

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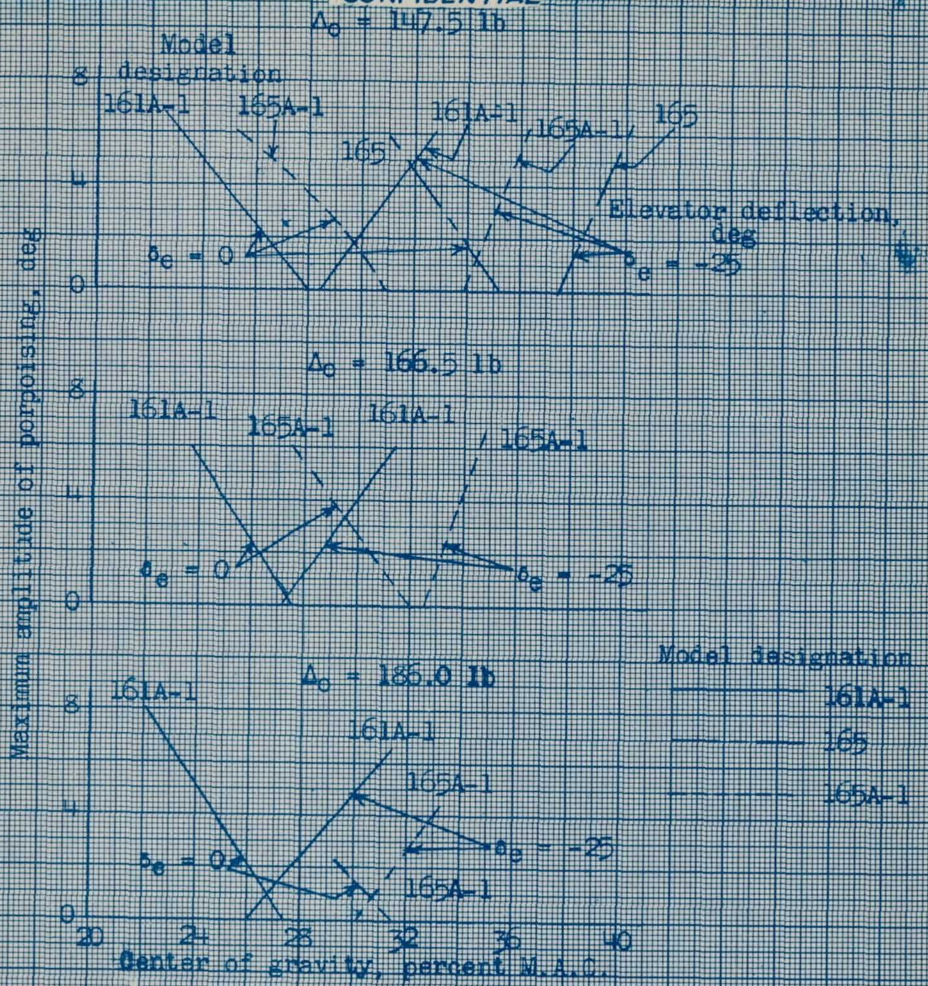

Figure 13.- Models 161A-1, 165, and 165A-1. Variation of maximum amplitude of porpoising with position of center of gravity. $\delta_f = 20°$.

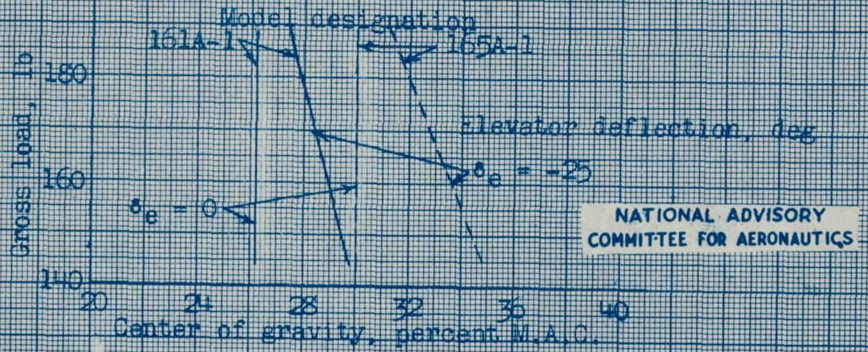

Figure 14.- Models 161A-1 and 165A-1. Variation of stable range of center of gravity positions with gross load. $\delta_f = 20°$.

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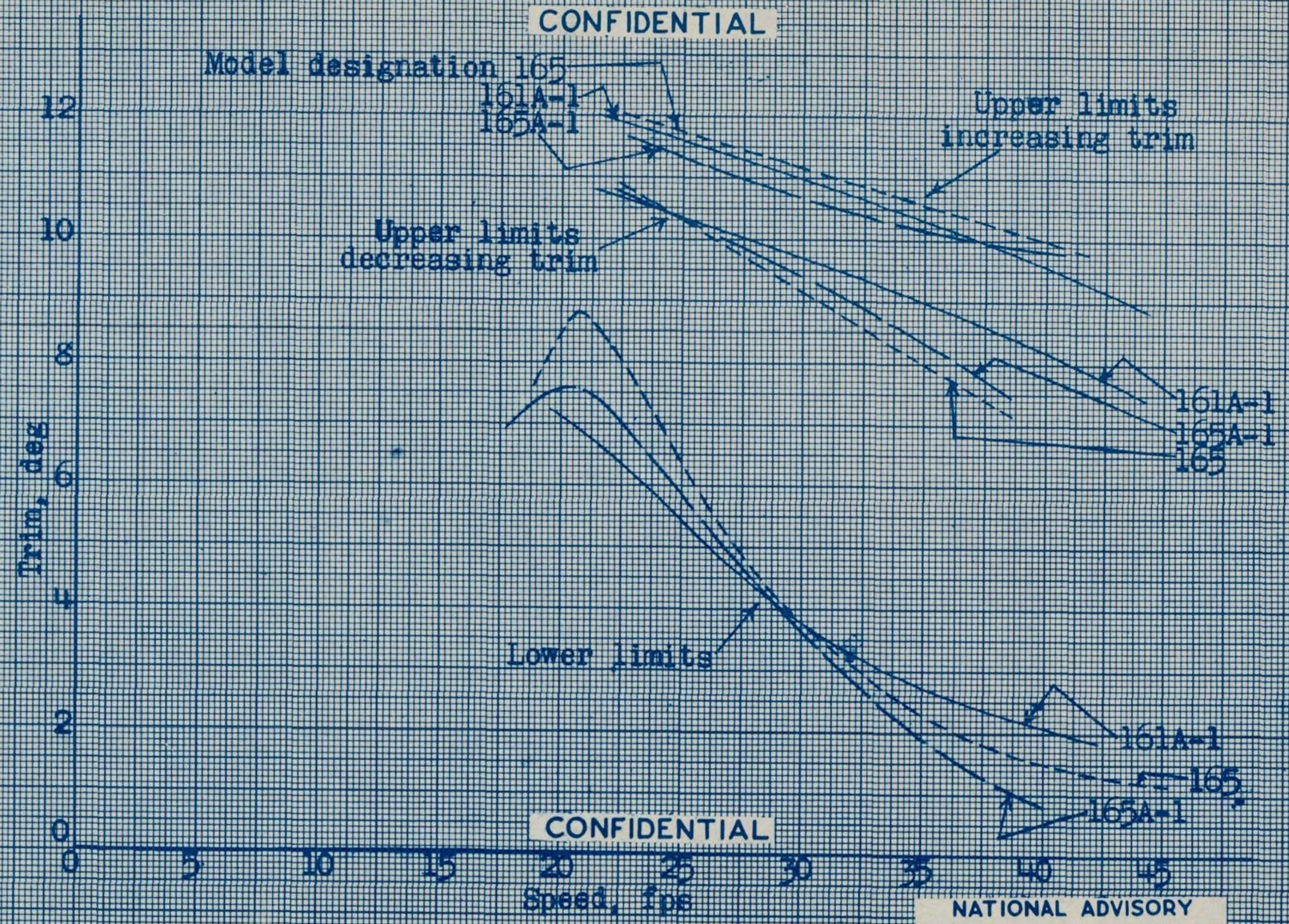

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Figure 15.- Models 161A-1, 165, and 165A-1. Comparison of trim limits of stability. $\Delta_0 = 147.5$ pounds; $\delta_f = 20^{\circ}$; propeller rpm, 6900.

[redacted]

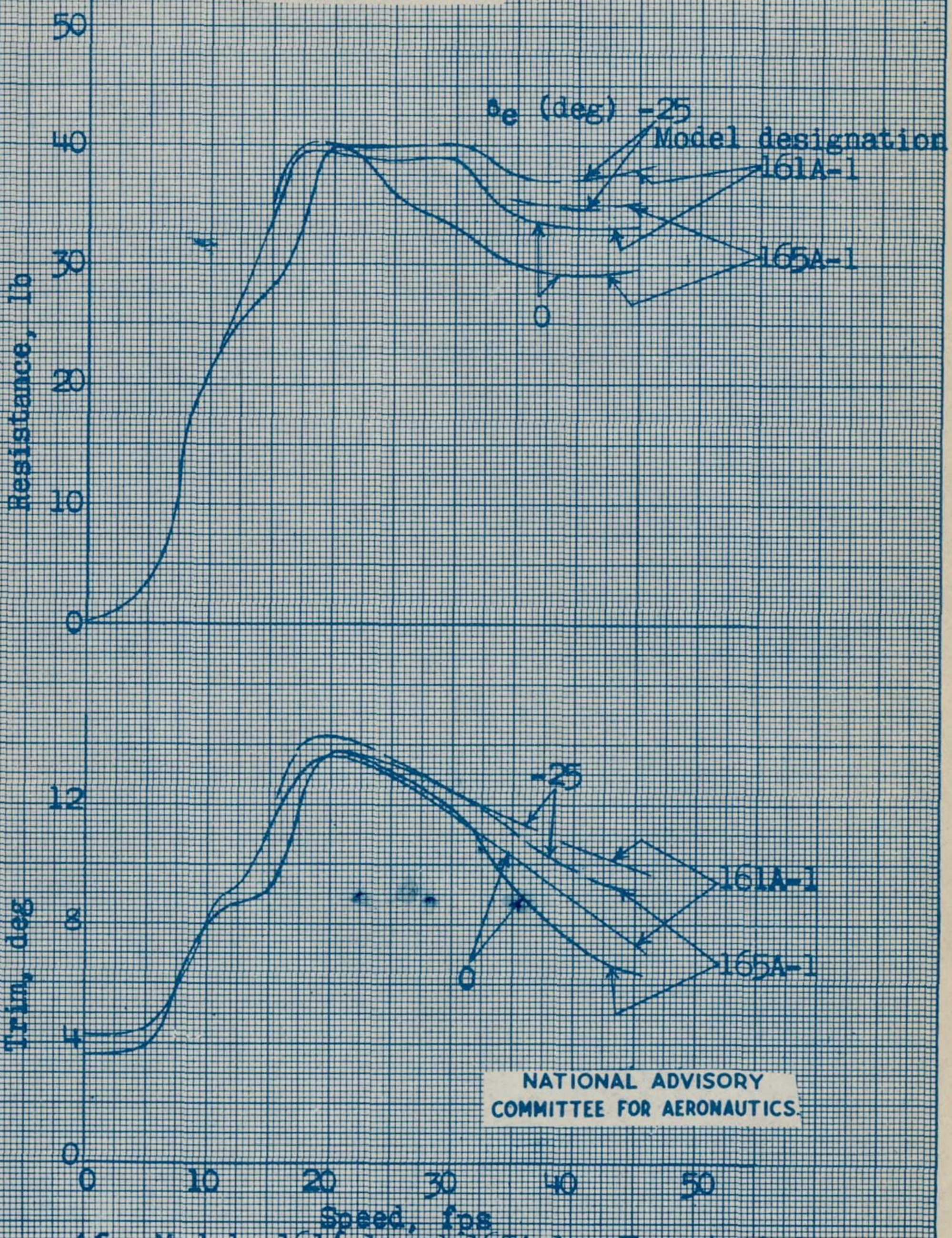

Figure 16.- Models 161A-1 and 165A-1. Free-to-trim resistance without power. Δ_0 = 147.5 pounds $\delta_f = 20^\circ$; center of gravity 28 percent mean aerodynamic chord

[redacted]